Fabrication of High Resolution CZT Detectors

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Summary of detector parameters using both 1000- and 3000-Å barriers.

Epi-growth		
Composition	Thickness	Doping
$Hg_{0.7}Cd_{0.3}Te$	1000 & 3000 Å	Undoped
Wafer		
n - type, growth on 211 orientation, 10^{-9} cm		

It is an important national security need to be able to ubiquitously deploy high-resolution (preferably room temperature) gamma detectors in the field to provide unambiguous identification of special nuclear materials (SNM) as well as other potential threats.

The energy resolution for semiconductor-based gamma detectors is defined as the full width at half maximum (FWHM) of a peak divided by the energy of the peak. The ideal characteristic would be an impulse function. This, however, is not the case in practice and the detected signals can be challenging to resolve and interpret. At present, the only commercially available room-temperature (E_g = 1.6 eV) alternative to cryogenically-cooled germanium (Ge) detectors is based on Cadmium Zinc Telluride (CdZnTe), which has a resolution of about 10 times worse than Ge-based gamma detectors. The cooling requirement of Ge is an encumbrance and a room temperature detector is greatly preferred. It is critical to have very-high-resolution gamma detectors for unambiguous identification of SNM, so as to avoid false alarms. Only the cryogenically-cooled Ge material is able to resolve the SNM signatures with high certainty. Much improvement in CdZnTe is necessary.

There are two approaches that can be taken to improve the resolution of CZT. The first approach is by increasing the resistivity of the CdZnTe material, which will reduce the current through the device. The second approach is to change the physical layer configuration of the device. In this work we will grow lattice-matched materials on CdZnTe

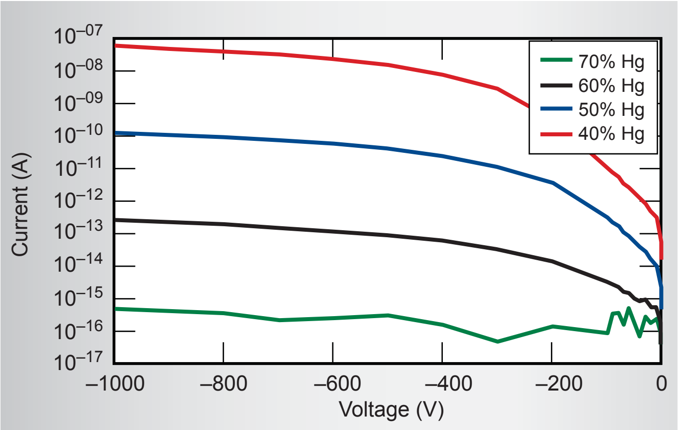

Figure 1. Silvaco simulations of voltage vs. current for various Hg compositions for the $Hg_xCd_{1-x}Te$ blocking layer. The simulations show that a dramatic decrease in leakage current through the device can be achieved with 70% Hg composition.

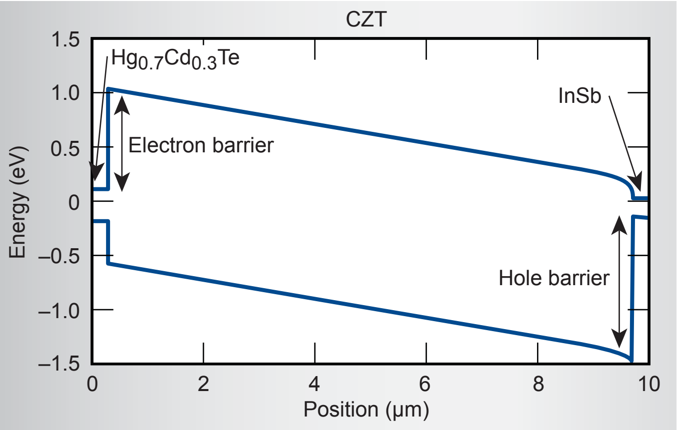

Figure 2. Silvaco simulation of HgCdTe/CZT/InSb radiation detector.

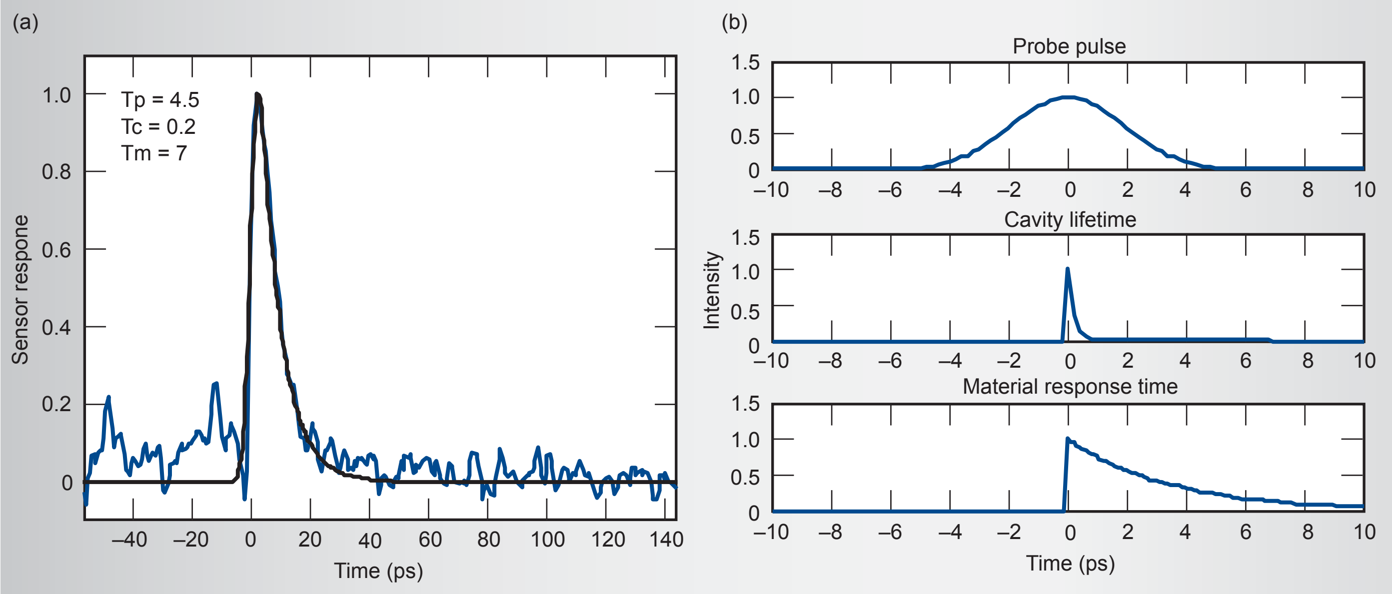

Figure 2. (a) Measured ROPER sensor response using pump-probe techniques and above-bandgap optical excitation of the sensor. The signal is the convolution of the probe pulse, cavity temporal response, and material temporal response (b). The analysis indicates a material response time of ~7 ps.

InGaAsP technology was used for the 1535-nm application.

Relevance to LLNL Mission

This project specifically addresses the instrumentation requirements of Weapons and Complex Integration (WCI). It is well aligned with institutional Science and Technology Plan thrust areas in Weapons Science (“Advanced Experimental Platforms Including Diagnostics”) and Discovery Class Science (“Beyond-State-of-Art Instrumentation and Measurement Capabilities”). The project enhances LLNL’s core competency in measurement science at extreme dimensions. In addition, we anticipate that, when available, ICF and HEDP experimental programs will identify applications for these detectors.

FY2008 Accomplishments and Results

In FY2008 we successfully combined the radoptic and ion-implant technologies in a reduction-to-practice effort yielding ROPER sensors with approximately picosecond temporal response. This was demonstrated experimentally in pump-probe measurements using above band-gap optical excitation of the sensor medium. The excitation pulse was ~200 fs from a mode-locked Ti:sapphire laser and regenerative amplifier operated at 780 nm. The probe pulse was generated using an optical parametric amplifier pumped by the same Ti sapphire oscillator. Figure 2a illustrates the measured sensor response of ~7ps. This is a convolution of the probe pulse, the material response time, and the sensor cavity lifetime, illustrated in Fig. 2b.

Related References

1. Lowry, M. E., C. V. Bennett, S. P. Vernon, R. Stewart, R. J. Welty, J. Heebner, O. L. Landen, and P. M. Bell, *Rev. Sci. Inst.*, **75**, pp. 3995–3997, 2004.
2. Bennett, C. V., and B. H. Kolner, *IEEE J. Quant. Electr.*, **36**, pp. 430–437, 2000.
3. Lambsdorff, M., J. Kuhl, J. Rosenzweig, A. Axmann, and J. Schneider, *Appl. Phys. Lett.*, **58**, 1881, 1991.

Project Summary

H^+ ion implant techniques were used to fabricate radoptic ROPER radiation sensors with approximately picosecond temporal response. This represents a five-order-of-magnitude improvement in sensor response time. (ROPER sensors using undamaged material exhibit response times ~ 200 ns.) The spatial distribution and intensity of the ion dose can be selected to tune and optimize both the temporal response and the detection sensitivity of the ROPER sensor for specific radiation detection applications.